CHAPTER THREE

Bipolar Junction Transistors

Digital Electronics.

Introduction

- This chapter describes:
  - Ebers-Moll BJT model
  - BJT modes of operation

Skip sections 3.1-3.5

Ebers-Moll BJT Model

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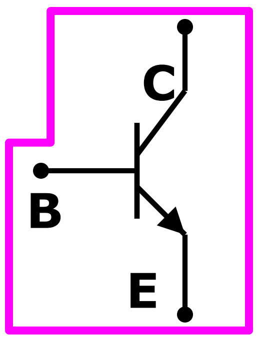
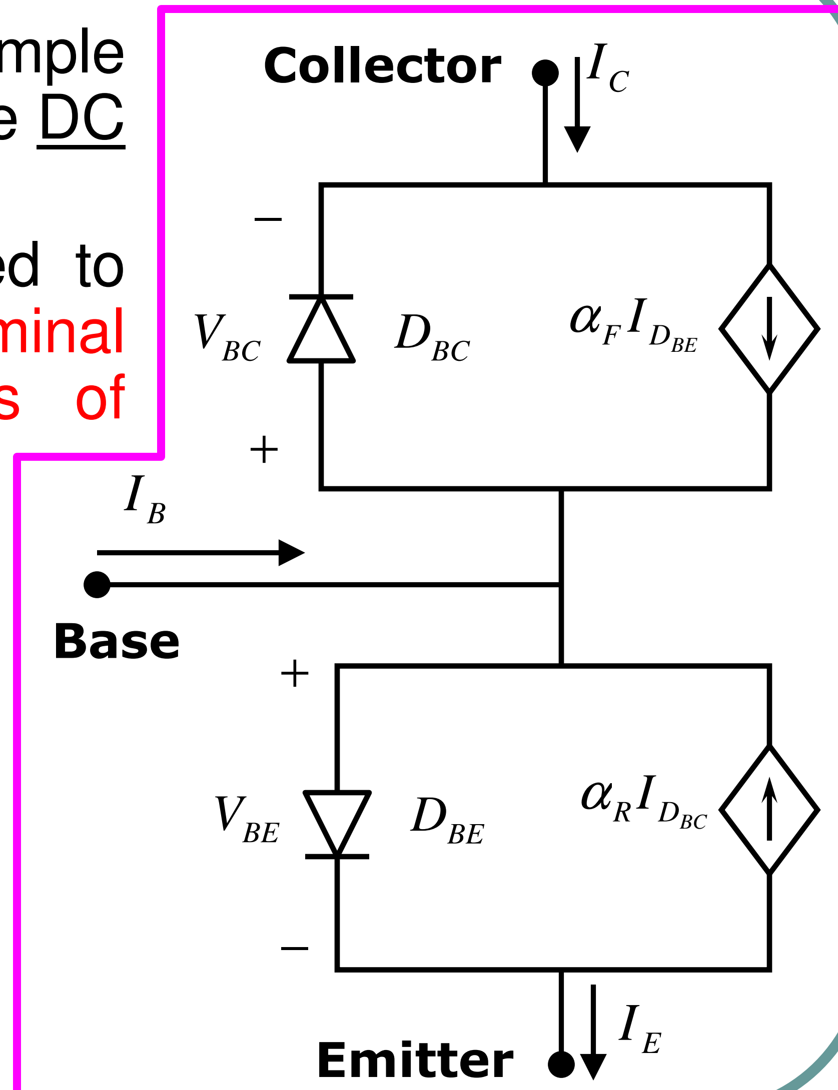
- Ebers-Moll model is a simple model that represents the DC operation of a BJT
- This model can be used to calculate the terminal currents for all modes of operation





Ebers-Moll BJT Model

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E	B	C

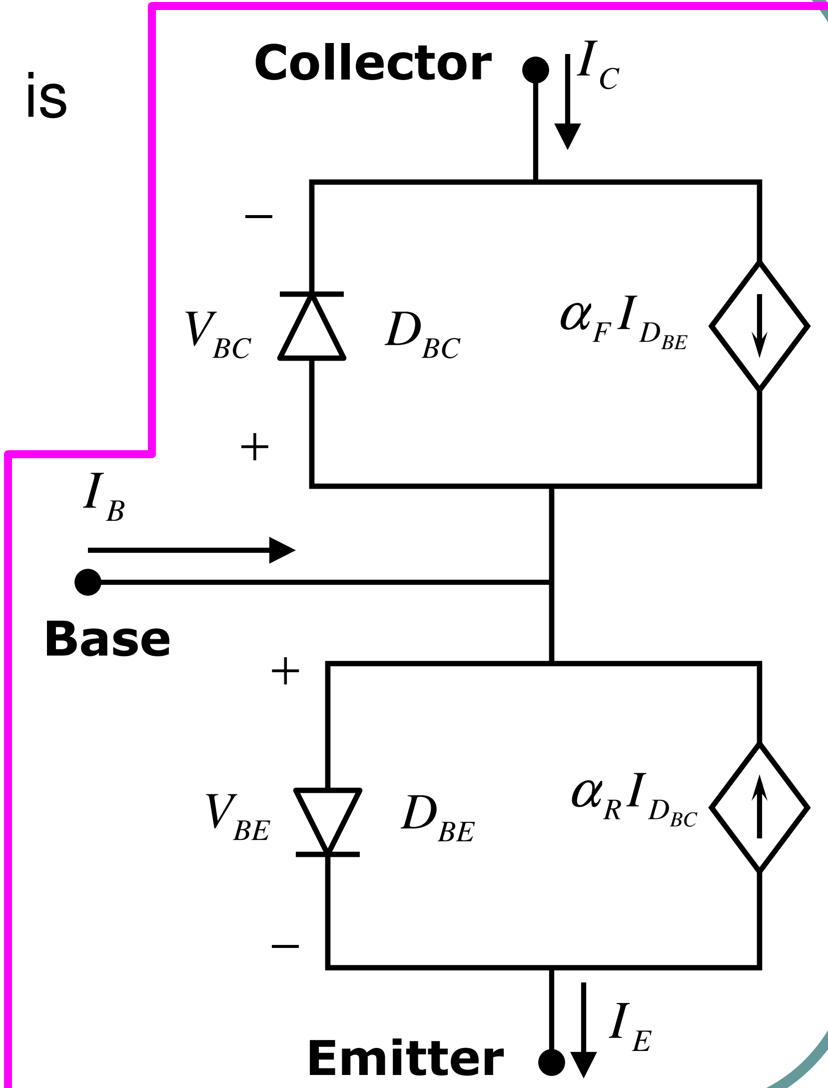
- The Base-Emitter junction is represented by

$$I_{D_{BE}}(V_{BE}) = I_{ES}\left(\exp\left\{\frac{V_{BE}}{\phi_T}\right\} - 1\right)$$

- I_{DBE} consists of electrons emitted from the emitter through the base toward the collector(current is opposite). A fraction of these electrons reach the collector and represented by

$$\alpha_F I_{D_{BE}} = \alpha_F I_{ES}\left(\exp\left\{\frac{V_{BE}}{\phi_T}\right\} - 1\right)$$

$0.98 \le \alpha_F \le 0.999$ Common-base forward current gain



Ebers-Moll BJT Model

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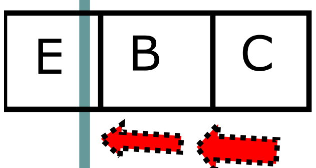


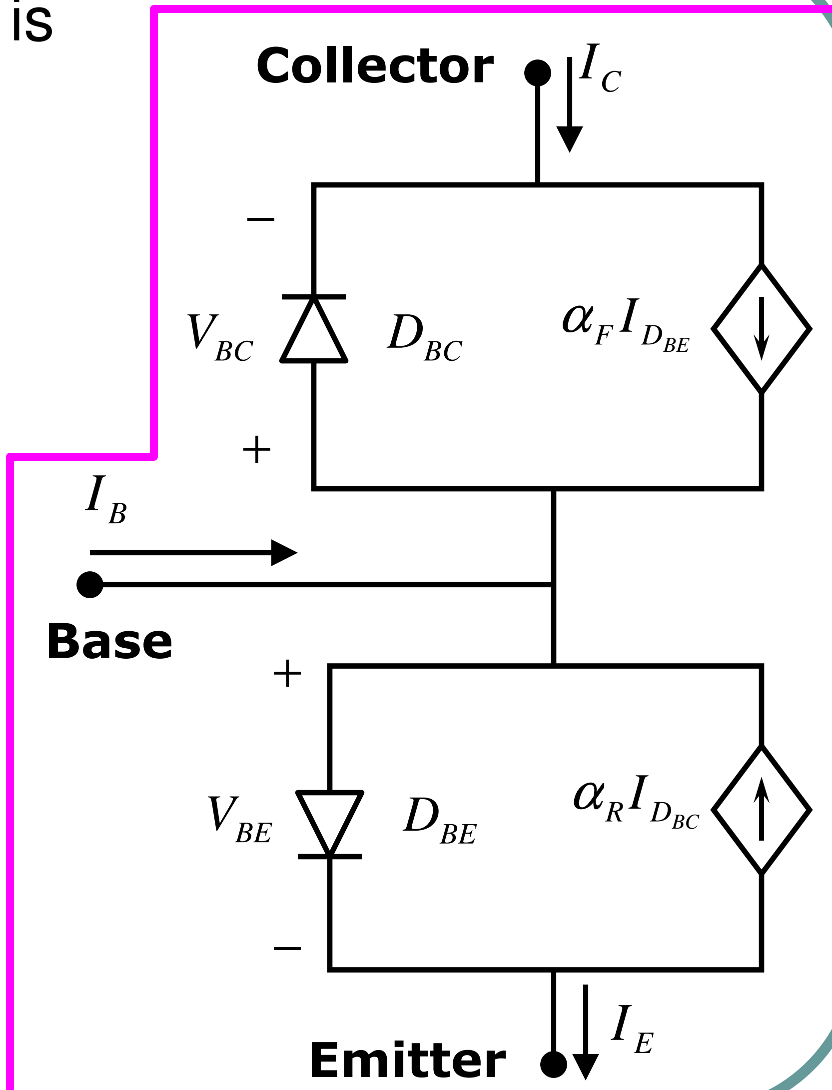
- The Base-Collector junction is represented by

$$I_{D_{BC}}(V_{BC}) = I_{CS}\left(\exp\left\{\frac{V_{BC}}{\phi_T}\right\} - 1\right)$$

  - I_{DBC} consists of electrons emitted from the collector through the base toward the emitter (current is opposite). A fraction of these electrons reach the emitter and represented by

$$\alpha_R I_{D_{BC}} = \alpha_R I_{CS}\left(\exp\left\{\frac{V_{BC}}{\phi_T}\right\} - 1\right)$$

$0.2 \le \alpha_R \le 0.6$ Common-base reverse current gain



Ebers-Moll BJT Model

$$I_E = I_{ES}\left(\exp\left\{\frac{V_{BE}}{\phi_T}\right\}-1\right)-\alpha_R I_{CS}\left(\exp\left\{\frac{V_{BC}}{\phi_T}\right\}-1\right)$$

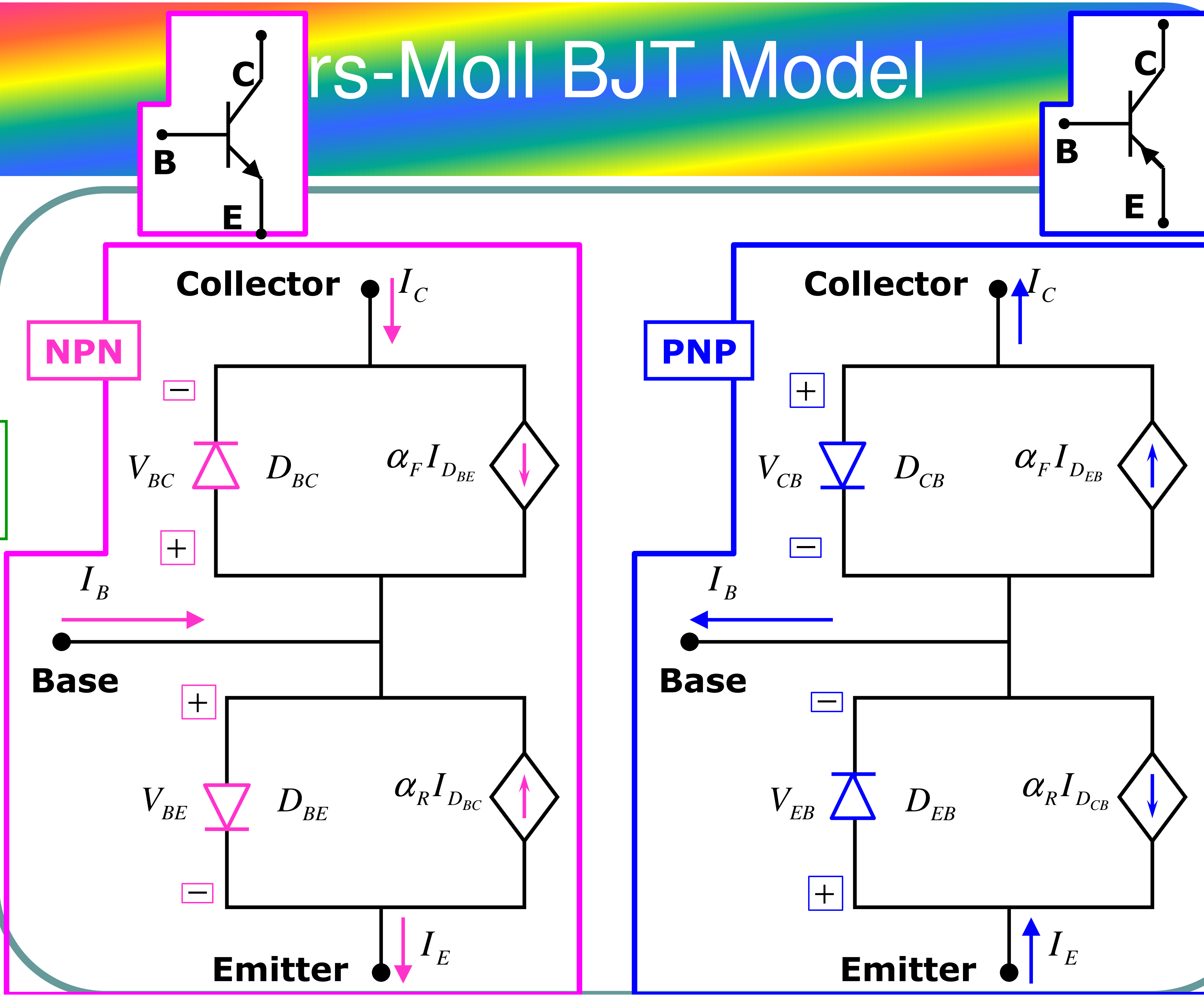
and

$$I_C = -I_{CS}\left(\exp\left\{\frac{V_{BC}}{\phi_T}\right\}-1\right)+\alpha_F I_{ES}\left(\exp\left\{\frac{V_{BE}}{\phi_T}\right\}-1\right)$$

and

$$I_B = I_E - I_C$$

rs-Moll BJT Model



Modes of Operation

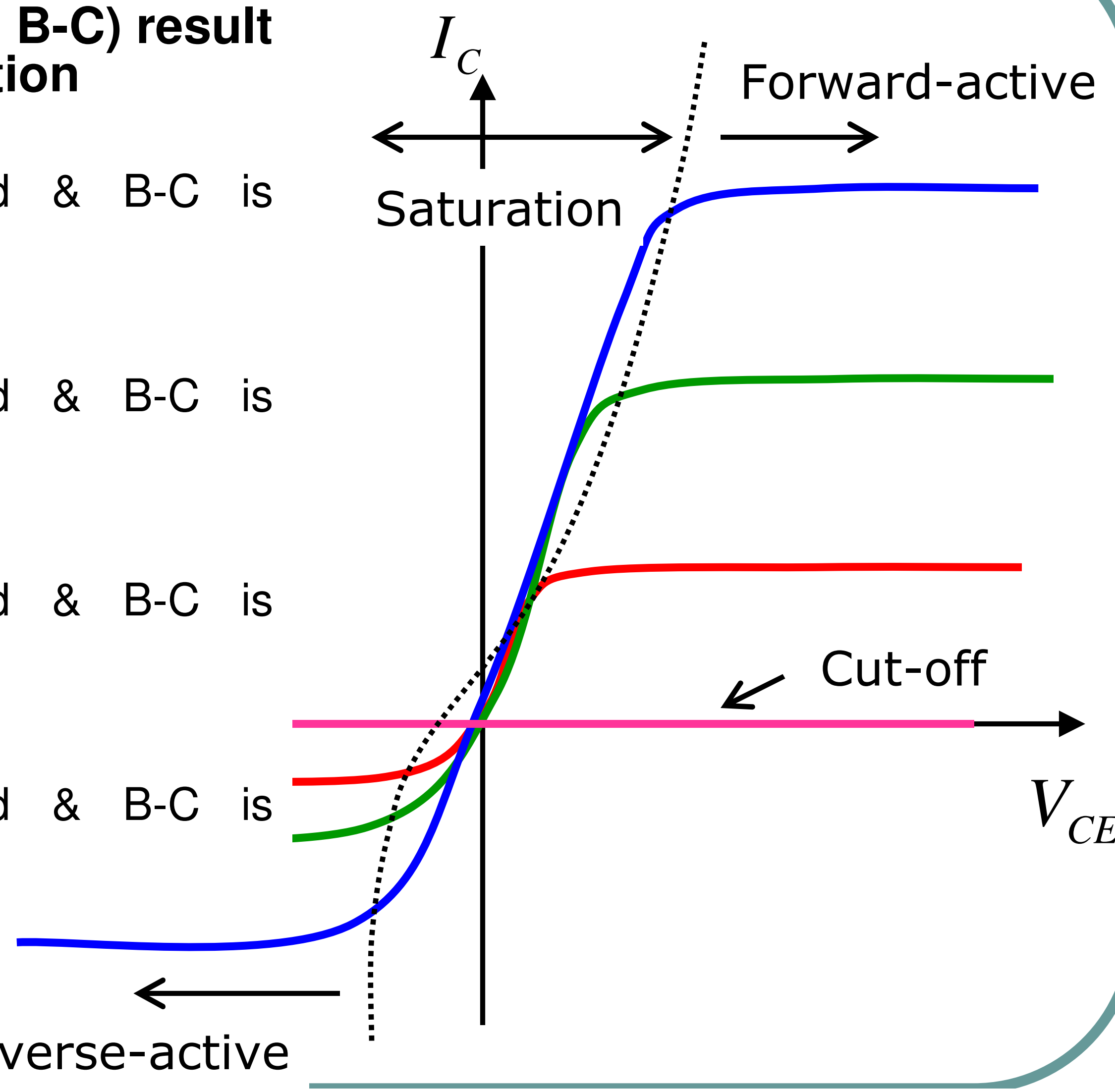
- **Two junctions (B-E and B-C) result in <u>four</u> modes of operation**

1. B-E is reverse-biased & B-C is reverse biased
   (Cut-off mode)

2. B-E is forward-biased & B-C is reverse biased
   (Forward-active mode)

3. B-E is reverse-biased & B-C is forward biased
   (Inverse-active mode)

4. B-E is forward-biased & B-C is forward biased
   (Saturation mode)



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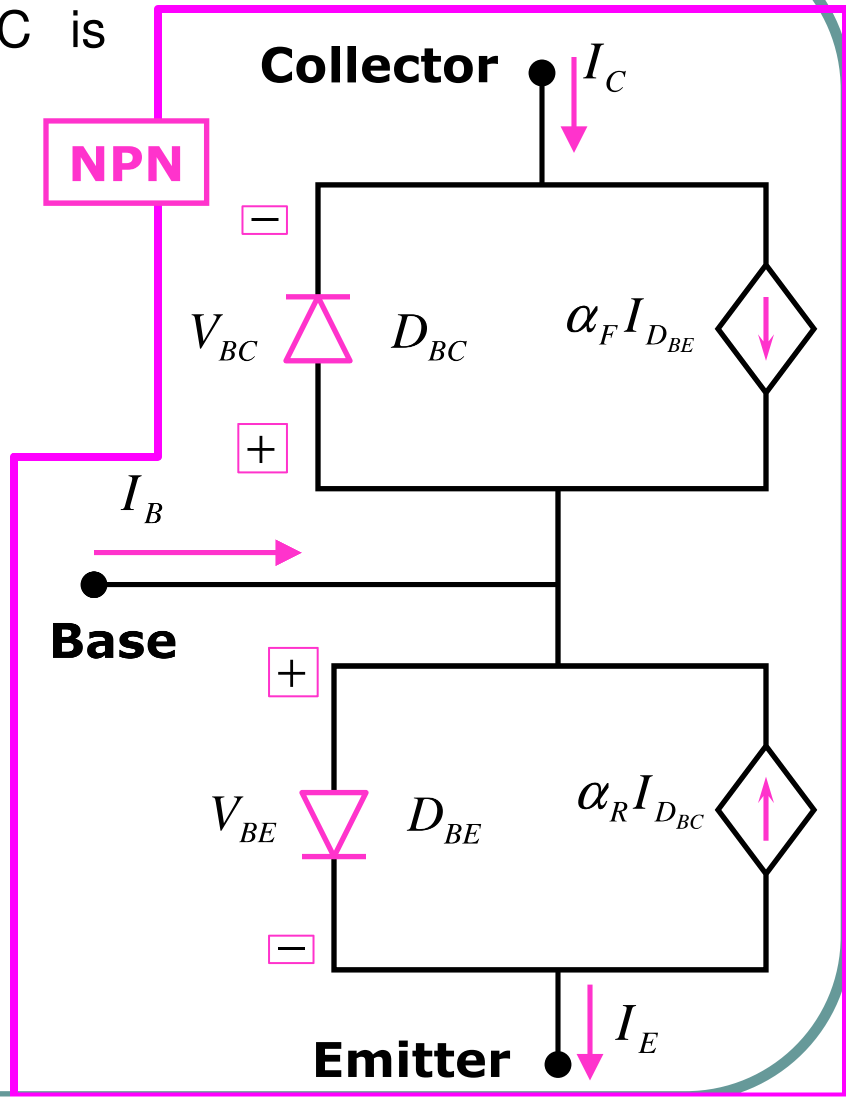
Modes of Operation

1. B-E is reverse-biased & B-C is reverse biased (Cut-off mode)



Modes of Operation

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1. B-E is reverse-biased & B-C is reverse biased (Cut-off mode)

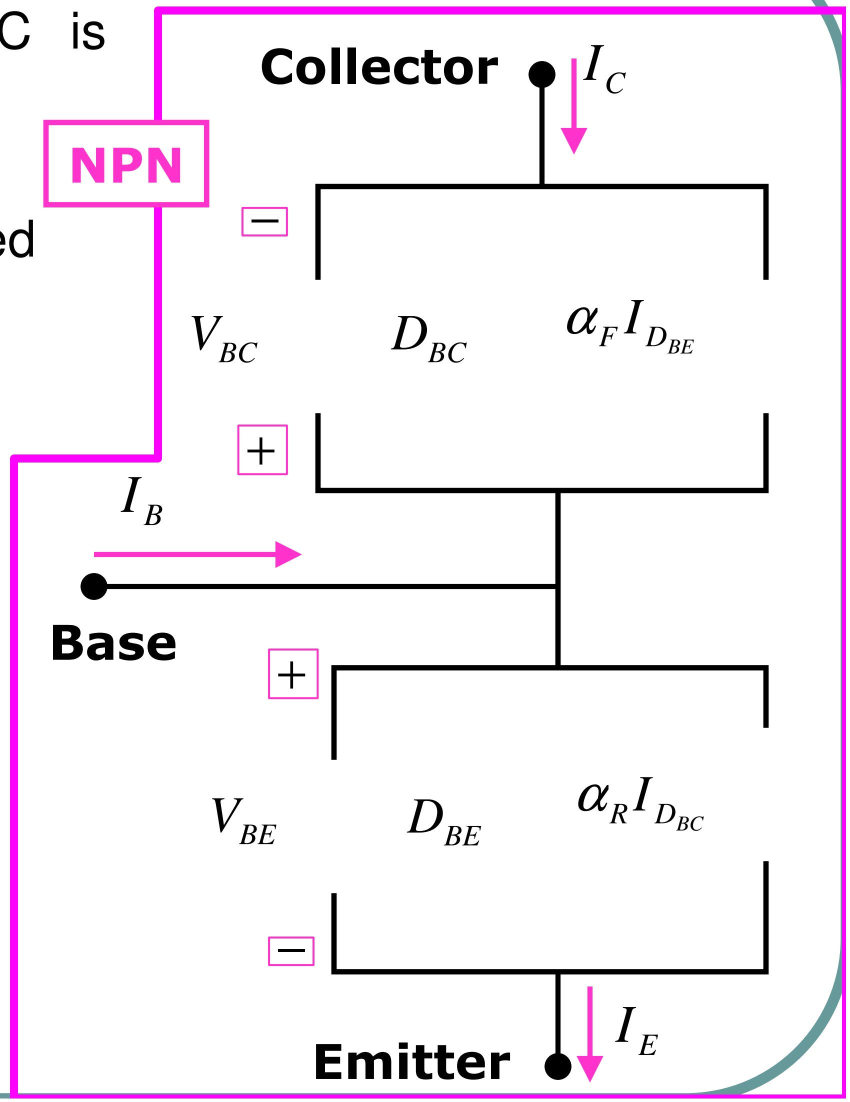
Both D_{BE} and D_{BC} are reverse-biased

Both I_{DBE} and I_{DBC} are Zero

$$I_E \approx 0$$

$$I_C \approx 0$$

$$I_B \approx 0$$



Modes of Operation

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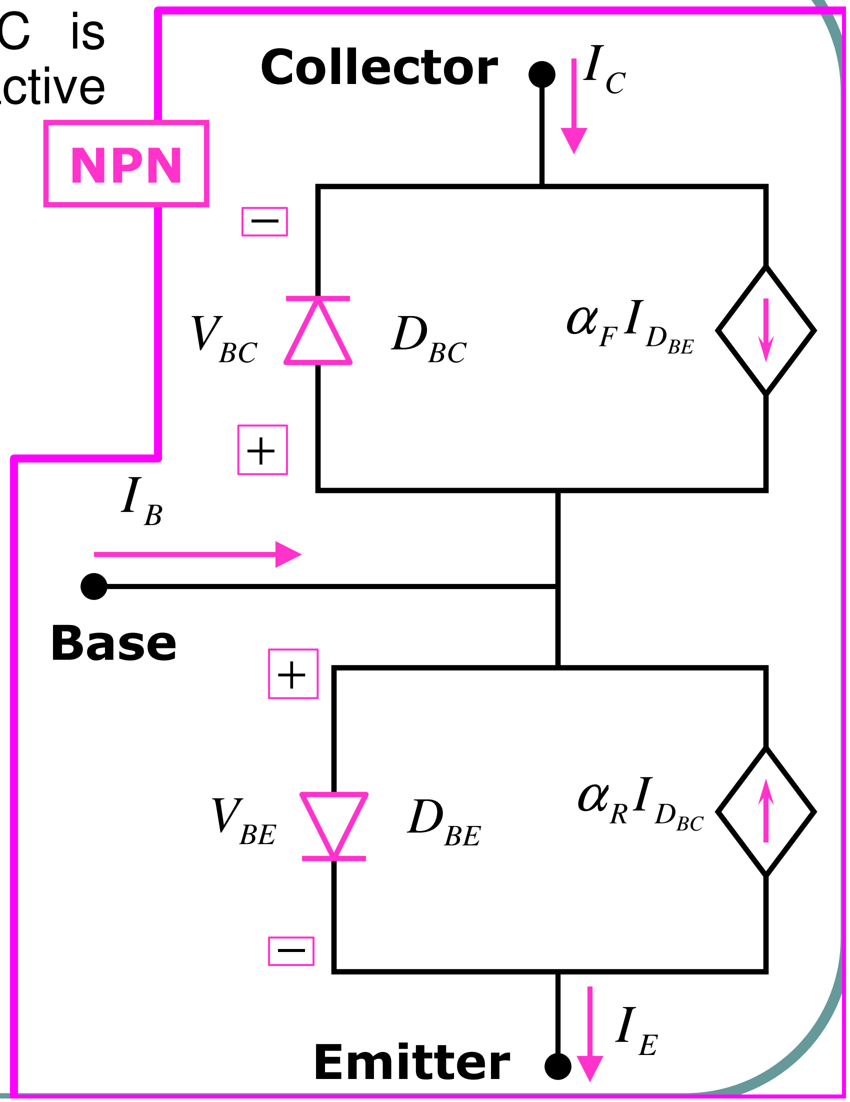
2. B-E is forward-biased & B-C is reverse biased (Forward active mode)



Modes of Operation

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2. B-E is forward-biased & B-C is reverse biased (Forward active mode)

Both D_{BE} is forward biased with V_{BE}=0.7 V (*silicon diodes*) while D_{BC} is reverse-biased (open)

i.e. I_{DBC} is Zero

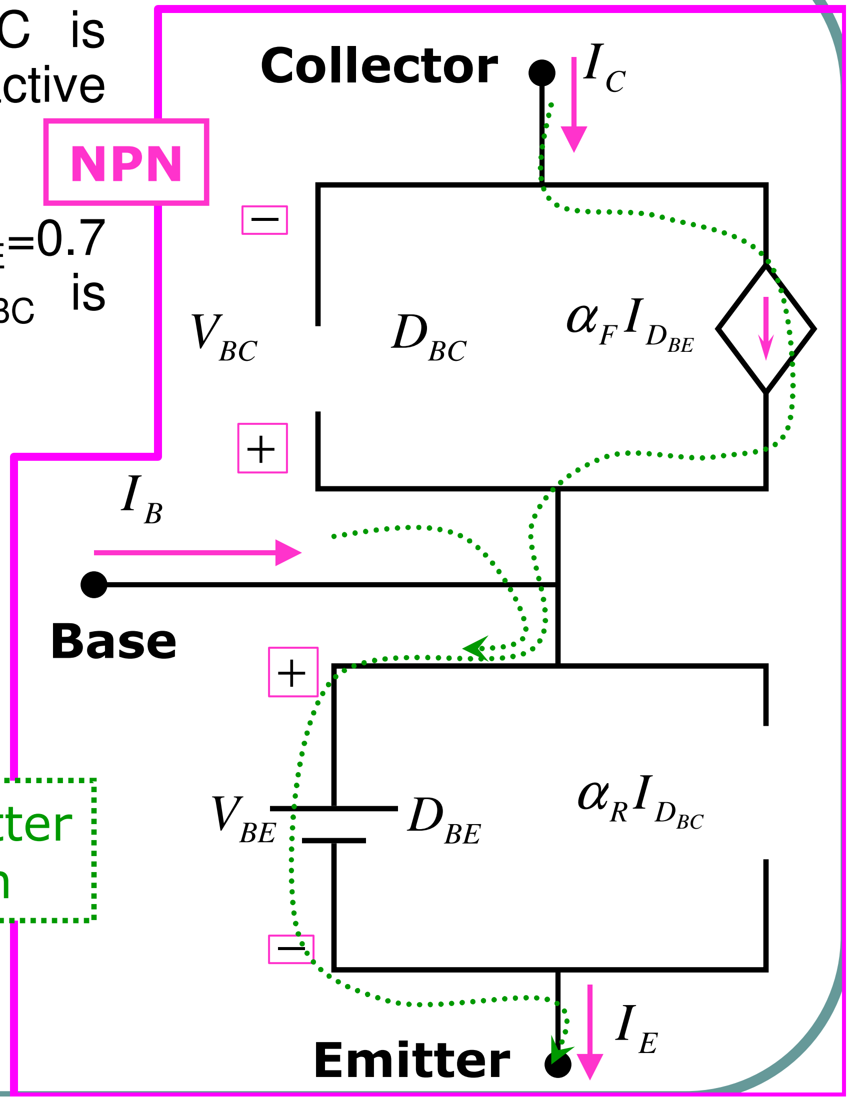
$$V_{BE}(F.A.) = 0.7V$$

$$I_C = \alpha_F I_{D_{BE}} = \alpha_F I_E = I_E - I_B$$

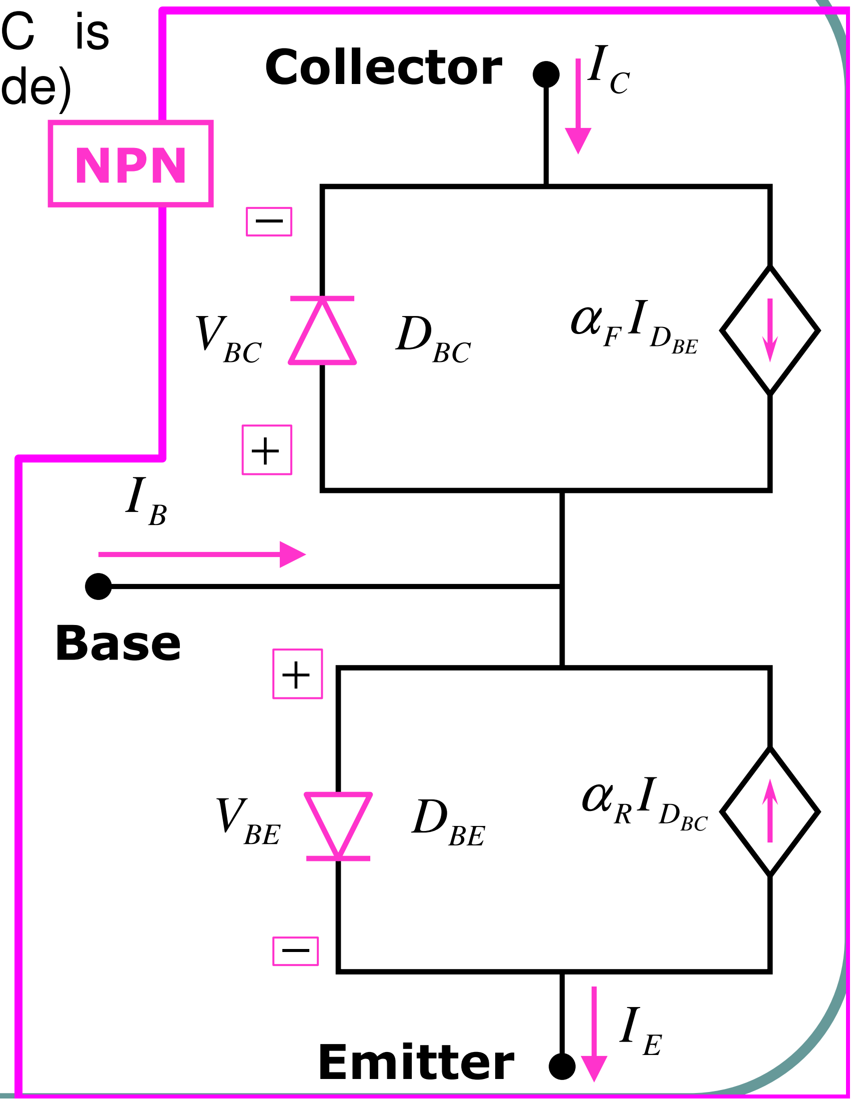
$$I_E = \frac{I_B}{1-\alpha_F}$$

$$I_C = \alpha_F \left(\frac{I_B}{1-\alpha_F} \right) = \beta_F I_B$$

Common-emitter current gain



3. B-E is forward-biased & B-C is forward biased (Saturation mode)



Modes of Operation

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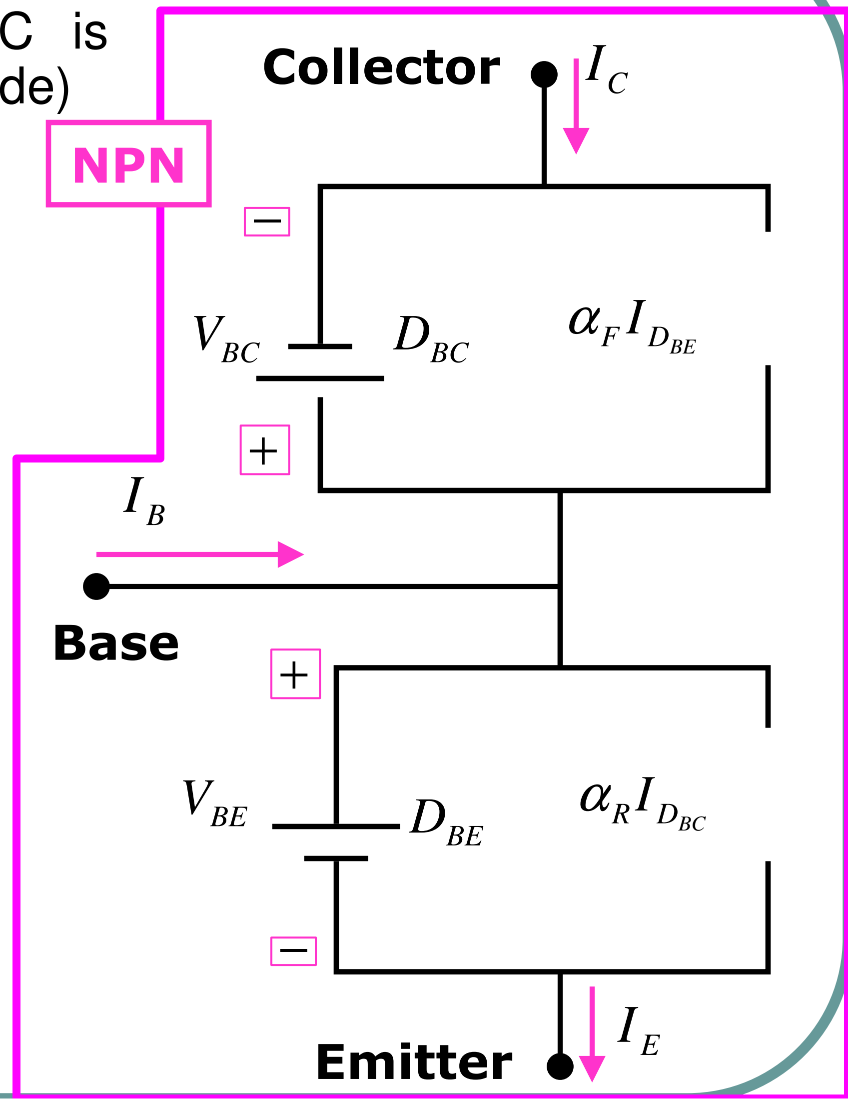
3. B-E is forward-biased & B-C is forward biased (Saturation mode)



$$V_{BE}(sat) = 0.8V$$

$$V_{BC}(sat) = 0.6V$$

$$V_{CE}(sat) = 0.2V$$

$$\sigma = \frac{I_C}{\beta_F I_B} = \begin{cases} 1 : F.A. \\ < 1 : Sat. \end{cases}$$

Modes of Operation

Ch 3

4. B-E is reverse-biased & B-C is forward biased (Inverse-active mode)

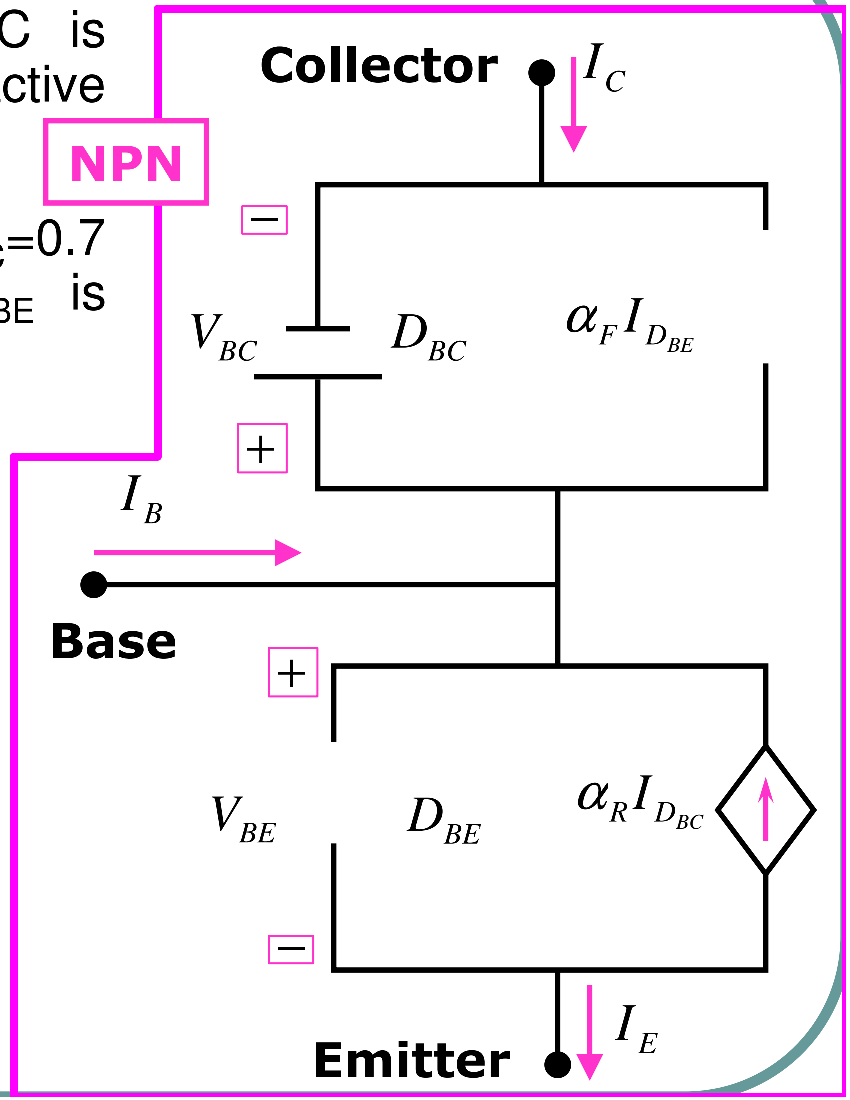
Both D_{BC} is forward biased with V_{BC}=0.7 V (*silicon diodes*) while D_{BE} is reverse-biased (open)

i.e. I_{DBE} is Zero

$$V_{BC}(R.A.) = 0.7V$$

$$I_E = -\alpha_R I_C = -\frac{\beta_R}{\beta_R + 1} I_C$$

$$\beta_R << \beta_F$$



- HW #3:Solve Problems: 3.8, 3.9, 3.14